Just In Time MANET:
A New Network Architecture

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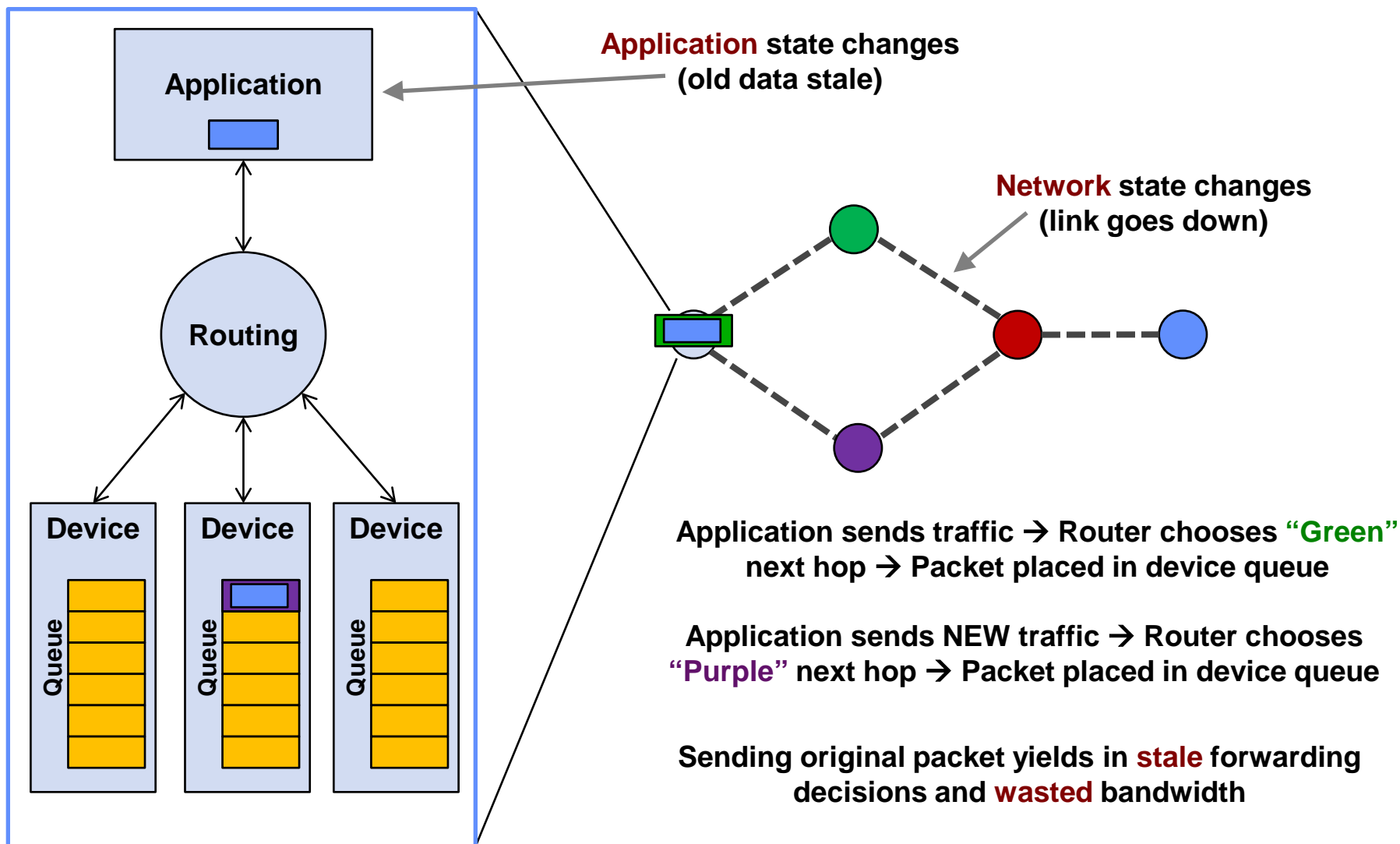
Outline

- **Traditional Architecture**
- **JIT MANET Architecture**
- **JIT MANET Components**
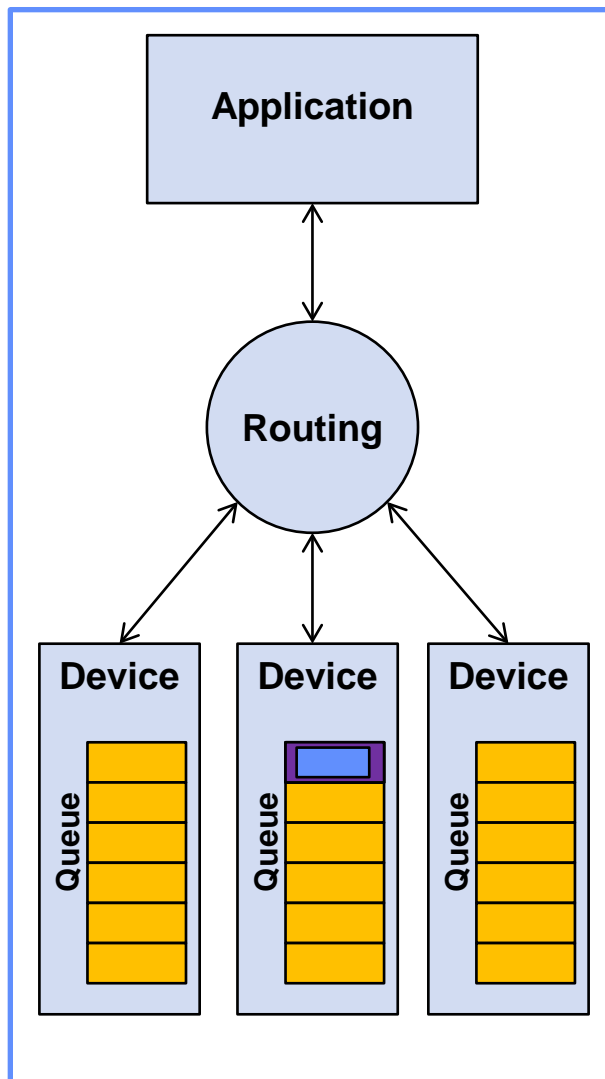- **Advantages/Research Challenges**
- **Conclusion**

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Traditional Network Architecture
Following a Packet

Application state changes
(old data stale)

Network state changes
(link goes down)

Application

Routing

Device   **Device**   **Device**

Queue   Queue   Queue

Application sends traffic → Router chooses "Green" next hop → Packet placed in device queue

Application sends NEW traffic → Router chooses "Purple" next hop → Packet placed in device queue

Sending original packet yields in stale forwarding decisions and wasted bandwidth

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Traditional Network Architecture
Inefficiencies and Limitations

Application

Routing

Device | **Device** | **Device**

Queue | Queue | Queue

Application Layer
- **Unable to account for stale information after being sent (Application state change)**
- **Unable to fuse content that is redundant**
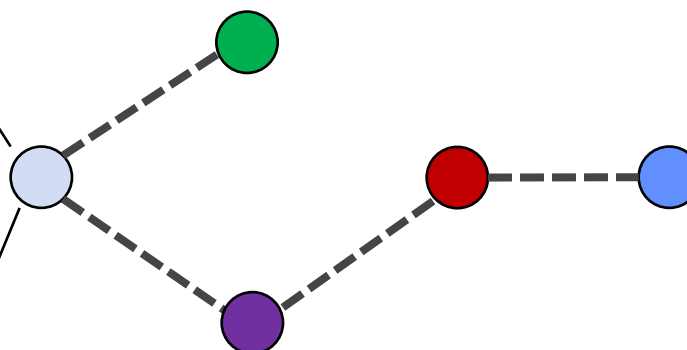
Network Layer
- **Response to link changes might be stale**
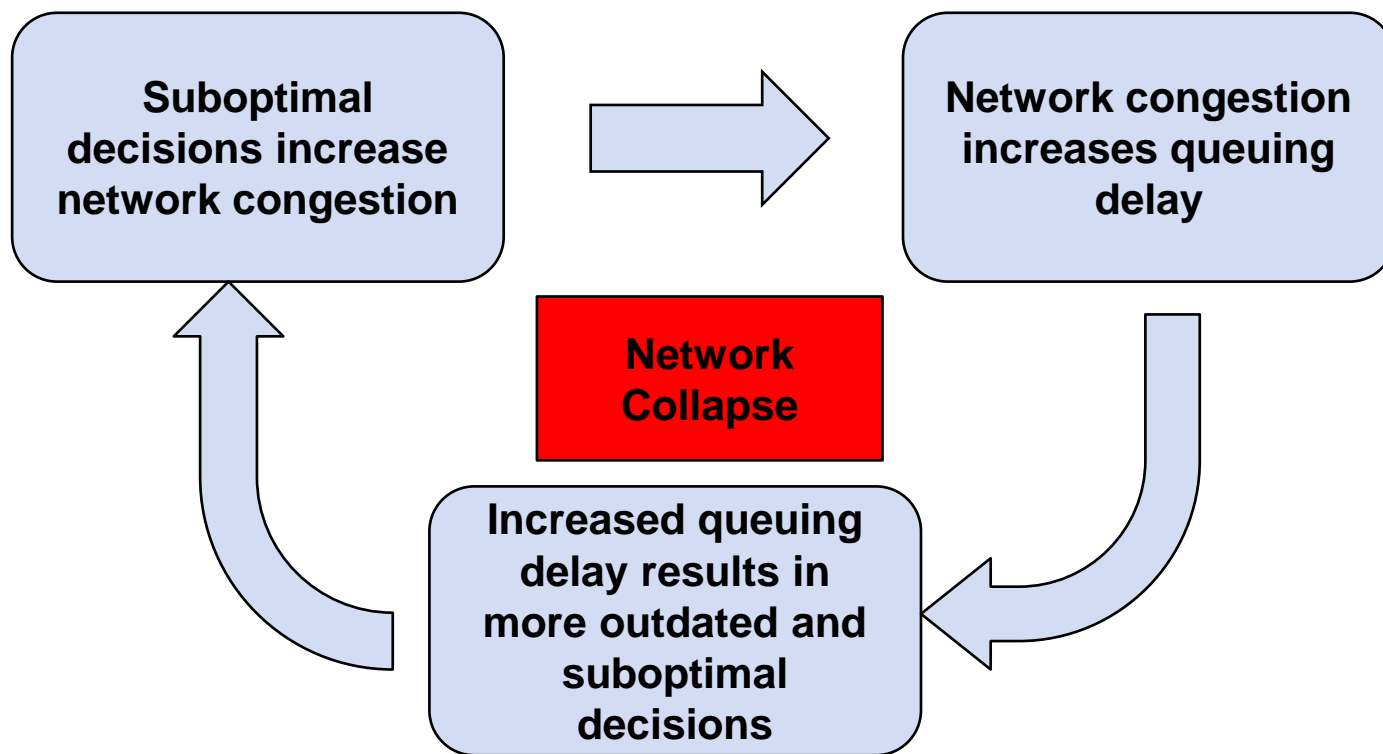- **Routing decisions stale by transmit time**

Link/Phy Layer
- **Queue build-up with stale content and packets**
- **Bandwidth inefficiency with stale information**
- **Re-transmissions to unavailable neighbor**

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MANET Scalability

- **In traditional network architecture, even with perfect network state information, queuing delays make network and application decisions suboptimal. This is inherently unstable.**

Suboptimal decisions increase network congestion

Network congestion increases queuing delay

Network Collapse

Increased queuing delay results in more outdated and suboptimal decisions

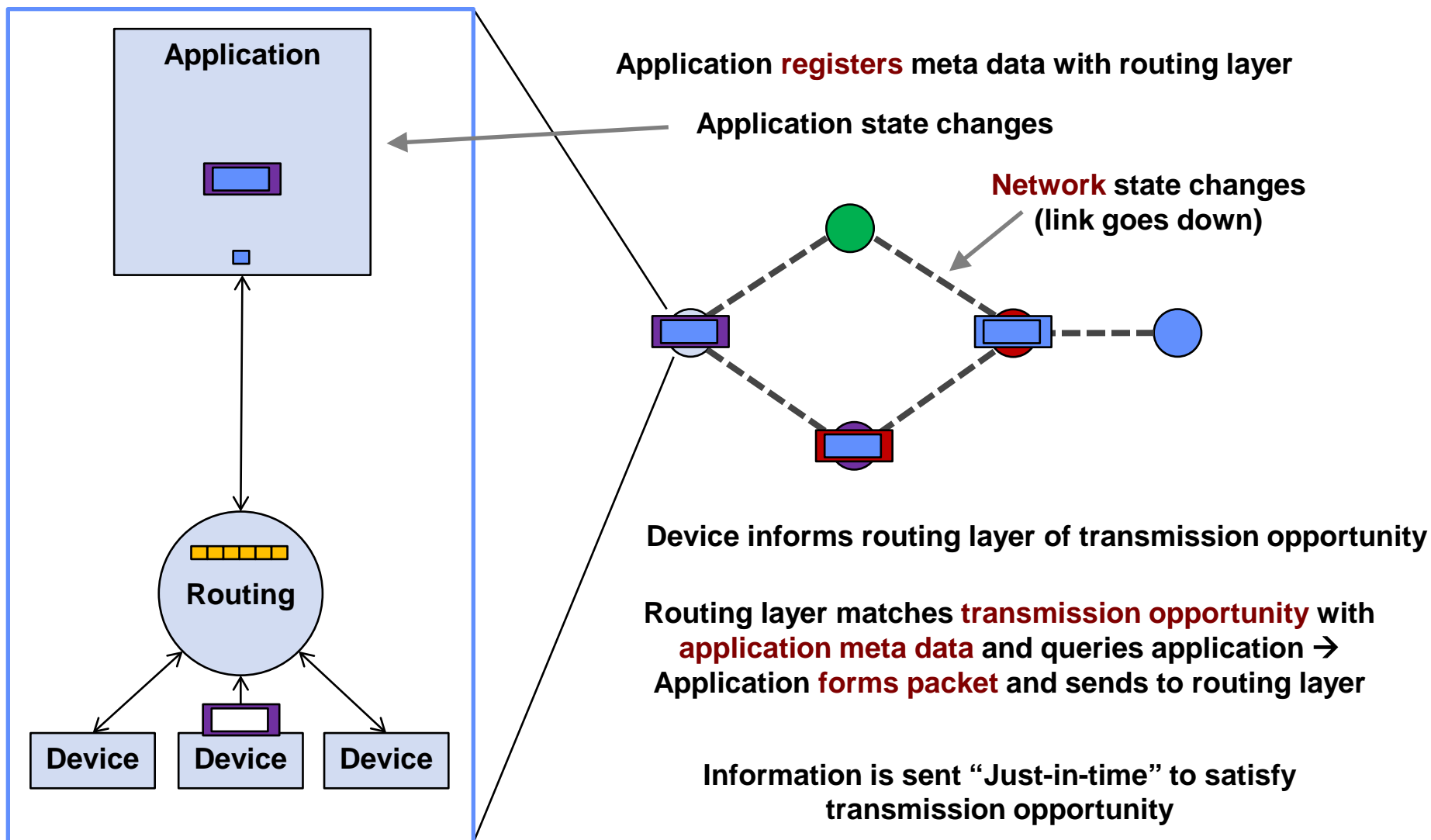**LINCOLN LABORATORY**
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Just In Time MANET

- **Avoid network collapse by breaking the cycle**
  - **Maximize freshness of routing for a packet decisions at the time the packet is transmitted**

- **Just-in-time routing**
  - **Routing decision made when the packet is transmitted**

- **Just-in-time packet creation**
  - **Application data and routing information packets contain the most up to date information available at the time the packet is transmitted**
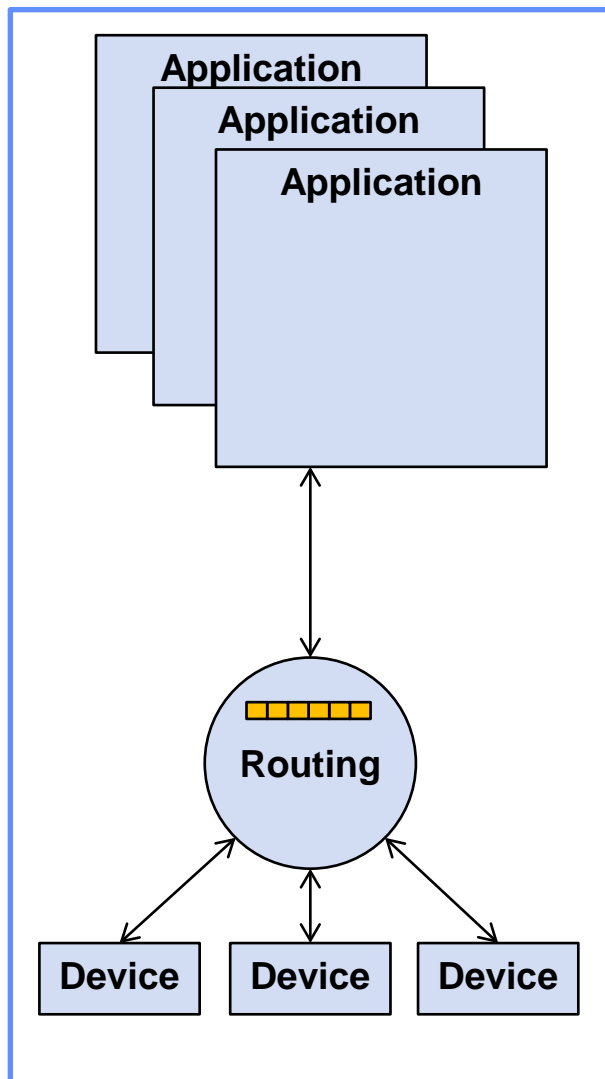
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Just In Time MANET
Following a Packet

Application registers meta data with routing layer

Application state changes

**Network state changes
(link goes down)**

Device informs routing layer of transmission opportunity

**Routing layer matches transmission opportunity with
application meta data and queries application →
Application forms packet and sends to routing layer**

**Information is sent "Just-in-time" to satisfy
transmission opportunity**

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Just In Time MANET
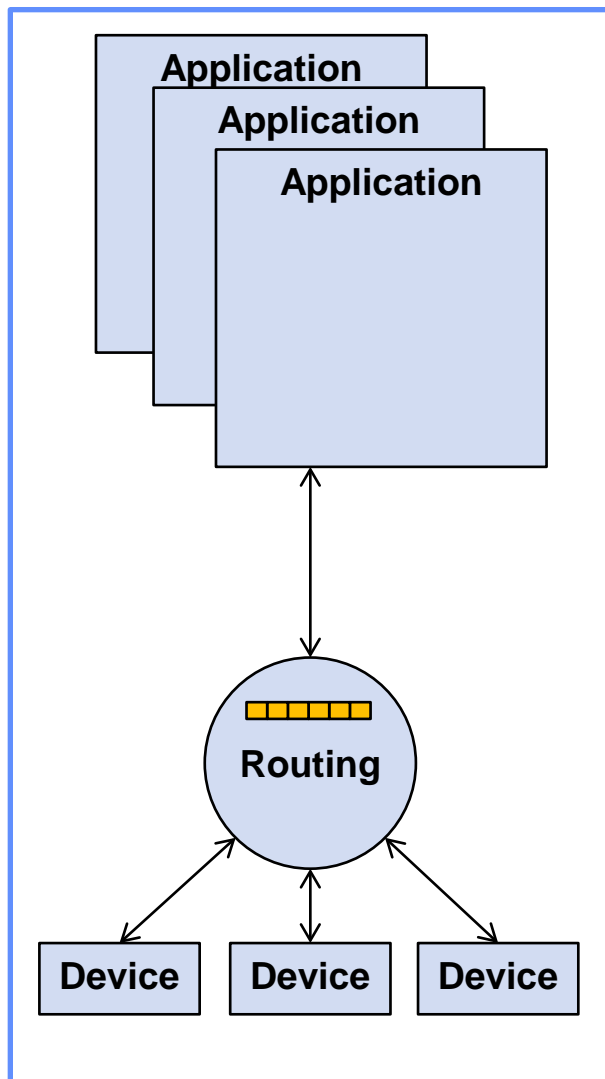## System Architecture

- **Applications**
  - **Need to be able to register traffic demands with routing layer**
  - **Traffic demands should specify characteristics of demand**
    - **Destination**
    - **Amount of data / demand expiration time**
    - **Frequency of transmission**
    - **QoS**
   - **Time required to create packet**

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Just In Time MANET
System Architecture

Application
Application
Application

Routing

Device   **Device**   **Device**

- **Routing**
  - **Needs to map device transmission opportunities to application demands instead of mapping packets to their next-hops**

- **Device**
  - **Needs ability to recognize transmission opportunities in advance to request packets**

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Just In Time MANET
System Architecture
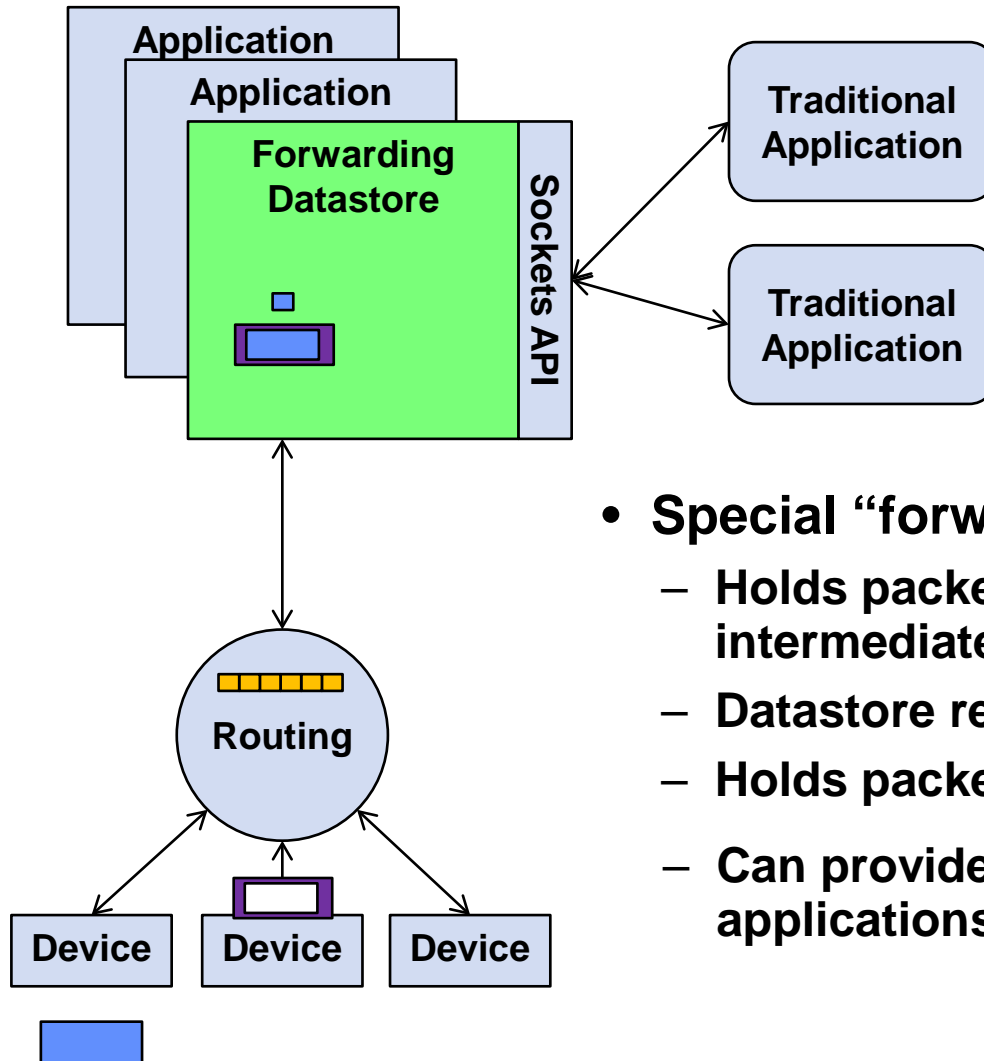
- **Special "forwarding datastore" application**
  - **Holds packets traversing multiple hops at intermediate nodes**
  - **Datastore registers appropriate demands**
  - **Holds packets until time of transmission**
  - **Can provide BSD sockets interface to local applications to allow them to run unmodified**

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Advantages

- **Richer interface between network and application**
  - **Provides more information about upcoming traffic to enable global planning**
  - **Allows applications to send the most up-to-date information**

- **1 hop freshness guarantee**
  - **All data transmitted in the 1 hop neighborhood and routing decisions made use best information available at time of transmission**
    - **Most data in MANET transmitted only a few hops [Ramanathan et al. 2010]**

Advantages

- **Allows for more efficient networking**
  - **Can use backpressure type algorithms for network-wide congestion management and routing**
    - **Backpressure algorithms shown to be throughput optimal [Tassiulas et al 1992]**
    - **Incorporating traffic generation rate information may allow optimality of backpressure algorithms without significant increases in delay**
  - **Easily allows path diverse routing**
    - **Decisions made at time of transmission**
  - **Better global network decisions**
    - **Integrated routing, QoS, and congestion control**

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Advantages

- **Multi-hop traffic held in "forwarding datastore" at intermediate nodes.**
  - **Could be adapted for information compression/fusion at intermediate nodes**
  - **Would allow for storage of content-based traffic**
  - **Allows for transparent application of delay tolerant networking**

- **Compatible with both content-based traffic as well as traditional point-to-point and point-to-multipoint traffic**

- **Allows for application-specific queuing control at source**

- **Easily interfaces with existing applications through sockets interface gateway**
  - **Allows existing applications to still work**
  - **Applications that require real-time control of data transmitted use new interface (e.g. routing, VOIP, adaptive video streaming)**

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Research Challenges

- **Completely changes networking paradigm**
  - **Device drivers and medium access algorithms need to be able to predict transmission opportunities in advance**
  - **Routing layer needs to be able to quickly match device opportunities to application demands**
    - **How can good decisions be made quickly?**
    - **What decisions can be made just in time?**

- **New architecture changes constraints of existing research**
  - **Algorithms for integrated routing, QoS, and network-wide congestion control**
  - **Interactions between application, network, and link layers**

- **Opportunity to investigate combinations of content-based networking with traditional networking**

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JIT MANET Comparison Summary

	Traditional Networks	JIT MANET
Architecture	PUSH	PULL
Routing	Rule-based	Case-by-case
Queuing	At device	In application
Packet construction	Before device-layer queuing	After App-layer queuing, before transmission
Per-packet processing required	Low	High
Decision Freshness	As old as queuing delay	Fresh at transmission
Stable near network capacity	No	Potentially

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Questions?

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- R. Ramanathan, R. Allan, P. Basu, J. Feinberg, G. Jakllari, V. Kawadia, S. Loos, J. Redi, C. Santivanez, and J. Freebersyser, "Scalability of Mobile Ad Hoc Networks: Theory vs practice," In Proceedings of IEEE *MILCOM 2010*.

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Backup

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MANET Context Assumptions

- **Low data rate channels (spectrum is scarce)**

- **High processing power/capability (Moore's law)**

- **Each node contains both router and applications**

- **High mobility**

- **Large network**

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